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Digitizing the Deep

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ABSTRACT

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Title of the Publication: Digitizing the Deep – A look into the disruption caused by VR and AR in the industrial landscape of mining, today and tomorrow

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Keywords: virtual reality, mining industry, marketing, market analysis

This thesis observes at the current landscape of the mining industry, as well as the development of Virtual and Augmented Reality technology, and through several brief case studies and analysis thereof through marketing theories, attempts to illuminate how these two fields can and do operate together.

For the past few years, the mining industry has been in decline, owing to the drop in demand, as well as several disruptions caused by both technological developments as well as geopolitical shifts.

This research attempts to find if Virtual and Augmented Reality would aid the sector in streamlining operation, cutting costs and overall revitalizing the productivity rates. The research method is that of literature review and case analysis based on secondary data and the application of several market theory viewpoints in order to ascertain relevant patterns.

This thesis contains four case studies from the mining industry.
The first one is Rio Tinto's Mine of the Future – project, which utilizes automation on a larger scale, such as Autonomous Haulage Systems, unmanned trains, and most importantly, a Remote Operations Centre.

That is followed by the case of Freeport McMoRan's endeavor of using drones to both monitor and evaluate the rock face in real time, boosting both safety and productivity while cutting costs.

Mira Geoscience's providing of hazard assessment software in 4D comes third, offering a visually dynamic alternative method to perform hazard assessments and general surveying.

Lastly, the joint effort of Rio Tinto, Anglo American and Newcrest Mining in using smart headwear to monitor the fatigue levels of their employees shall be observed for gaining further insight.

The theoretical frameworks used to analyze the aforementioned cases are, in order, the Technology Acceptance Model, the Theory of Reasoned Action, the PESTEL analysis, the Consumer Decision-Making Process, and finally the 7Ps of Marketing.

This is a developing market and as such it faces challenges as well as opportunities. This research includes a general analysis of those, including challenges like connectivity, threats like cyber-attacks, strengths like cost-effectiveness and opportunities like boosting individual potential.

In conclusion, it can be observed from the case studies that while the acceptance and adoption rate of Virtual and Augmented Reality varies notably on an individual company level, there is demonstrably a growing market for it and applications either entirely based on or partially using it.

FOREWORD

“Nothing in the world can take the place of persistence.
Talent will not; nothing is more common than unsuccessful men with talent.
Genius will not; unrewarded genius is almost a proverb.
Education will not; the world is full of educated derelicts.
Persistence and determination alone are omnipotent. The slogan, ‘press on’ has solved, and always will solve, the problems of the human race.”
-Calvin Coolidge

This thesis evolved from a certain CEMIS project that was in proposal stage while I was doing my practical training there, as well as my fascination by virtual reality and drones, as well as an interest in the mining sector.

All these combined and formed something that has been both a passion and a nightmare to make, prompting no small amount of frustration. This has been both a demonstration to my university and myself that I am ready to graduate.

Within the constraints of both time and the rules of academic writing, I have done my best to keep this thesis informative while not dry, maintaining hope that maybe someday someone besides the instructor will read it.

I would like to take this chance to thank prof. Anas Al-Natsheh, my supervisor, as well as CEMIS employees Joonas Tikkanen and Antti Rimpiläinen, as their guidance helped me work faster and more efficiently.

Finally, I would like to thank my fiancée for helping me keep sane during all this.

Cheers.

In Kajaani on 12.6.2018
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CONTENTS

1 OVERVIEW OF THESIS TOPIC AND STRUCTURE

1.1 Brief overview

To briefly summarize, the thesis will first familiarize the reader with history and concepts as well as practicalities of Virtual and Augmented Reality (henceforth referred to as VR and AR respectively), followed by an introduction to the mining sector globally.
Afterwards there will be both introduction and explanation of the theoretical methods applied in this thesis research.

Further, there will be case-by-case observations from around the world, and all existing trends will be analyzed looking through the chosen theoretical lenses. From there, prevailing trends and drivers in the chosen sector will be identified and further addressed.

Finally, based on all the gathered information and insights yielded by the theoretical analysis, there will be offered a tentative look into the future of VR and AR and their role in the mining sector, as well as conclusions that yours truly arrived to as a result of conducting this research.

1.2 Methodology overview

The method used in this case is literature review, as it was determined by the supervisor and yours truly to be the best method of collecting information on the subject at this time.

Unlike with many theses that focus more on the theoretical aspects of a given topic, this thesis, as it has a very real and tangible end goal, will mostly focus on the practical aspects of the cases, illuminating the theoretical principles as they manifest in reality.

To this end, the thesis contains several brief overviews, which after introduction are scanned through the theoretical lenses to help illuminate the practical mechanics of a given phenomenon.

2 INTRODUCTION OF VR/AR

2.1 General overview

Virtual and augmented realities, as they are generally defined today, are artificial (computer-generated) either add-ons or whole environments that can be observed or even interacted with in a “lifelike” manner. This is achieved with the help of either special, wand-like controllers, or specific wearable technology such as special helmets, goggles or headsets, and gloves and/or boots with sensors (What is virtual Reality, Virtual Reality Society (2017)). These are the basic requirements; however over time the interactions have been evolving and diversifying as will be elaborated on below.

VR/AR is currently used in various instances ranging from entertainment such as simulators and games to formidable aids in fields such as medicine and psychiatry. It is also used in first response training, geospatial measuring, driving, flying, engineering, big data analysis, architecture, landscaping, interior design, education, and finally, in mining, which will be the focus of this thesis research (Applications of Virtual Reality, Virtual Reality Society (2017)).

2.2 History

Throughout history, there has been a collective wish of humanity to immerse themselves in environments that are not real but feel like they are, or close to it. This has been demonstrated in things such as giant 360° murals and paintings painted by medieval artists, depicting fields of heavens in churches. Later came

the rotundas, the de-facto precursors to VR rooms. They were round buildings constructed for the sole purpose of displaying giant, panoramic paintings, and were furnished in style with the painting, adding to the immersion with various props (Into the belly of the image: Historical aspects of virtual reality, Oliver Grau, 1999).

In 1838, in a research conducted by Charles Wheatstone, a professor of Experimental Philosophy at King's College in London, it was established that one could create an illusion of three dimensions by using flat images (line drawings) and altering the angles slightly.
He dubbed his prototype invention "stereoscope" at a public unveiling in the same year and proceeded to hone it further. It should be noted that the stereoscope preceded the invention of photography (History of Virtual Reality, Virtual Reality Society (2017)).

That said, Wheatstone cannot be accredited as the sole inventor of VR, as rather than a singular project, the VR we know today has been an amalgamation of multiple and very diverse influences.
Over the decades as technology and sciences have evolved, VR and AR have been attempted to achieve through various approaches. For example, enhancing one's sensory experience when watching a movie by using a fan to simulate wind, various scents and even a vibrating chair, was accomplished by Morton L. Heilig (1926-1997) in 1962 via his invention "Sensorama" (Albert Alcoz, Visionary Film (2007).

2.3 Current situation

In present day, VR and AR are steadily approaching the scale and accuracy their makers have always envisioned.

Much has been accomplished thanks to the processing power of modern computers and shrinking of the hardware size, reducing VR environments from whole rooms or even buildings like panoramic rotundas to the size of a head-mounted display. The portability is developing further as wireless models are being perfected.

On application side, the uses are ever diversifying.
As was mentioned earlier, the application capabilities of VR/AR range widely, from purely entertainment-focused venues, which means chat simulators, games and to even specific VR movies, to more serious and somber fields like psychology and psychiatry, heavy industry and medical fields.

That means endeavors such as helping veterans deal with their PTSD by visualizing events as they occurred and working through them (Using virtual reality to treat PTSD, Motherboard 2014).
Other examples include architecture, landscaping, quarrying and mining, and medical simulations for research and practice purposes. (Applications of Virtual Reality, Virtual Reality Society 2017).

3 A LOOK AT THE INDUSTRIAL SECTOR OF MINING

3.1 General overview

The chosen industry sector of the thesis is one that is not often in the headlines of the world, but which contributes a staggering amount to the way our everyday life is structured.

Ores and minerals and the diverse uses that science, technology, and even culinary fields have for them; they keep our societies functioning in a very profound and fundamental way.

As will be elaborated below, mining has ancient origins and has significantly developed over the centuries, achieving ever-greater results with more safe and effective approaches as the level of our technology advances, which is in fact what the application of VR and AR technologies would seek to further reinforce and develop.

3.2 Brief history

Humanity has been delving into the earth to obtain its riches since antiquity. The blocks that the great pyramids of Giza consist of were carved out of the limestone quarry with very primitive tools such as ropes, rock hammers and copper rods (Probing Question: How were the Egyptian pyramids built? Marissa McCauley (2014)).

The field was revolutionized for the first time around 1600s when the use of primitive explosives to clear tunnels and large rock obstacles was introduced, then again in 1700s when steam-powered pumps, drills and improved explosives came along. (Hustrulid, Mero, & Clark, 1998)

Mining has always been a field of hard labor and no small amount of risks, both safety and environmental. Considering all possible negative events when mining, it has always been in the core objectives of mining enterprises of all sizes around the world to minimize injury to both personnel and the environment as effectively as their resources make it possible, while simultaneously capturing maximum value.

3.3 Current situation

Mining sector today is facing various challenges.

Weak global demand is arguably the biggest concern. The first decade of the 21st century was powerfully driven by the rise of China and its heavy investments in modernizing existing and building new infrastructure, also manufacturing and construction sectors in connection to rapid urbanization (Digital Transformation Initiative Mining and Metals Industry, World Economic Forum, 2017).

It was not expected to last. However, the consensus and future prediction was that other developing countries would take up China's torch in relation to commodity demand as they continue to develop. This, unfortunately, was disrupted by several factors, such as advancements in engineering and product usage in relation to several key metals and minerals. (Digital Transformation Initiative Mining and Metals Industry 2017; Tracking the trends 2018 the top 10 issues shaping mining in the year ahead. 2018; Calam, 2018).

In normal circumstances, this would be a good thing. However, if engineers and designers find a way to use a lesser amount of X mineral in a Y product, that necessarily means a loss for the miner of said mineral due to the product developer needing and thus buying less.

Another factor is that most of our current economies on the planet are circular and sustainable by design or strive to be; again, a factor that under everyday circumstances is great yet harms the given industry. (Digital Transformation Initiative Mining and Metals Industry, World Economic Forum, 2017).
To put this simply, who would need new ore mined if recycled metal does the job just as well and is cheaper to get because the obtaining is far easier.

Alternatively, in the worst-case scenario (for the industry that is) they might design a completely new apparatus for a given task and wholly stop buying X mineral or metal. (Tracking the trends 2018 the top 10 issues shaping mining in the year ahead. 2018)

There is, however, a small upside in the given scenario, being that the demand of certain metals and minerals might actually go up due to new and different specifications of new apparatus, however it is not enough to negate the loss.

The third factor to be pointed out here involves socio-economic development, namely, premature de-industrialization. What this means in practice is that developing countries de-facto skip the step of industrializing. There are few factors that could contribute to this happening: global companies for one, with their technology, expertise, resources as well as excess capacity. (Digital Transformation Initiative Mining and Metals Industry, World Economic Forum, 2017).

Excess capacity refers to the result of what occurred during the high demand period, when China was buying up heaps of metals and minerals as it rebuilt itself. To accommodate that demand, many big companies launched expansions to their operations.

The problem is that, by the time the demand died down, most of said expansions were still under development. Some companies abandoned said expansions, and have been bearing out the waste of time and resources this decision resulted in. Many, however, deemed that it would be more cost-efficient to finish the projects, or in the case of completion, to keep them running.
This has resulted in mines generating surplus commodities. The premature deindustrialization might alleviate this situation some; however, it is very much a case of fixing an issue but creating another one in the process. (Digital transformation initiative mining and metals industry. 2017; Tracking the trends 2018 the top 10 issues shaping mining in the year ahead. 2018)

Increasing customer requirements also play a role. With more recyclability and more alternative material, metal and mineral producers face increasing demands from their customers. (Tracking the trends 2018 the top 10 issues shaping mining in the year ahead.2018)

Trade flow disruptions caused most notably by the heightened political climate changes and turbulences around USA and Brazil, Europe and Asia have contributed to ending the commodity boom prematurely, causing growing resource nationalism and regulation, among other things. (UK Cabinet Office, 2014)

What that means in practice is that a given nation or region may implement ever stricter legislation and policies to secure maximum benefit and value to the host are from selling a given commodity. (Digital Transformation Initiative Mining and Metals Industry, World Economic Forum, 2017, UK Cabinet Office, 2014)

Widening workforce skill gaps are another worrying trend. One of the causes here is the aging of the current workforce, which makes their adapting to developing technology more difficult. (Digital transformation initiative mining and metals industry.2017; Tracking the trends 2018 the top 10 issues shaping mining in the year ahead.2018)

Finally, declining resource access and quality are the proverbial coup de grace, backing the industry into quite the corner.

This is where the industry disruption by VR/AR comes in.

While naturally it cannot solve all of the problems listed above, the consensus is that if applied correctly, it will alleviate many of the problematic current situations. (Mine of the future™.; Digital transformation initiative mining and metals industry .2017; Calam, 2018; Newport Consulting, 2018)
Some of the bigger influencers in the industry have already adopted and are utilizing some of these solutions, and it is expected to increase as the trend gains momentum. Going forward, said case studies will be introduced here and accordingly analyzed.

Something of note concerning the mining industry is that when it comes to technologies, it is an innovator in some respects and a cautious, late adapter in others. Considering how niche the field is, this is unsurprising.

The next segment will illuminate the various new possibilities created by VR/AR, demonstrating the various areas they will influence, as well as how they will do this.

4 POSSIBILITIES OPENED AND EXPANDED BY VR/AR

The World Economic Forum, in their whitepaper “Digital Transformation Initiative: Mining and Metals Industry” (Jan 2017), states the following:

“*Regardless of the specific technology involved, the impact of digital is not confined to a few industries or geographies.*
Mobile devices and apps, cloud, analytics, sensors, advanced robotics, virtual reality, cognitive computing and artificial intelligence are all digital technologies that have quickly influenced and upended conventional business models, customer relationships and industry roles. “

To give an example, it took several decades for the United States to start truly nationally using the telephone lines invented by Alexander Graham Bell, and progress to cell- and smartphones from there, which took another decade(Hochfelder, D. Alexander Graham Bell, American Inventor). However, what happened in Africa was that they de facto leapt over the land-line part and proceeded straight to mobile. This was an unprecedented development, and it encouraged novel approaches to commerce, innovation, and even financing, still reverberating to date (Deloitte, 2015).

We shall now proceed to briefly overview the following concepts as they were defined in the World Economic Forum’s whitepaper:

- Connected Workers
- Remote Operations Centers
- IT/OT Convergences
- Asset Cybersecurity
- Advanced Analytics and Simulation Modelling

There are more segments connected to the field mentioned in the whitepaper, such as 3D printing. However, those are not strictly VR/AR related applications, and thus shall not be covered beyond any relevant mentions in the interest of topic consistency.

The six aforementioned concepts fall under umbrellas of Digitally Enabled workforce, Integrated Enterprise, Platforms and Ecosystems, and Next-Generation Analytics and Decision Support respectively. (Digital Transformation Initiative Mining and Metals Industry, World Economic Forum, 2017).

4.1 Connected Worker

The Connected Worker concept refers to the digital enabling perhaps most directly. By using intelligent wearables such as glasses, tablets or watches, the company can keep track of the workers themselves as well as their surroundings in real time. (Mine of the future™.; Connected workers: The IoT industrial revolution2015; Ker, 2015; Newport Consulting, 2018)

Unlike, for example, automated operational hardware, which mostly replaces human workers with robots and AI, the digital enabling of the workforce refers to imbuing human workers with the benefits offered by factors like VR/AR, cloud data storage and internet access.

To give concrete examples, workers benefit from on-demand, real time flow of information and an instant connection to experts with critical field advice that allows them to make accurate diagnoses of the situation on the ground far faster and take decisive actions on the spot. This approach drastically cuts the time it used to take to relay information and respond to a situation.

How VR/AR relates to this is for example, a visual feed demonstrating the expert's advice in practice demonstrates to a worker what to do far better than any verbal explanation alone ever would.

Combining that powerful tool for expression and information relaying with the fact that the expert likewise can have a direct VR picture feed thanks to the worker's wearables (extremely useful in crisis situations where the worker is stuck in a partially collapsed tunnel and it is very dark) will illuminate the situation far better than explanations ever could (Mine of the future™; Connected workers: The IoT industrial revolution2015; Digital transformation initiative mining and metals industry.2017; Tracking the trends 2018 the top 10 issues shaping mining in the year ahead.2018).

4.2 Remote Operations Centre

Remote Operations Centre (ROC) means, in essence, an off-site "control room" that allows the personnel and experts stationed there to monitor and remotely assist work sites. Owing to near-global internet access, the ROCs can be essentially located anywhere in the world.
This significantly cuts the time needed for an expert to respond to a situation occurring at the site, as well as enables the expert to advise several sites if need be (Mine of the future™.; Digital transformation initiative mining and metals industry.2017).

In the past, the expert would have required to fly out to the site in person, examine the situation, then possibly fly back to the HQ to consult a database, and then either instruct the site personnel via telephone or email, or in worst-case scenario fly there again.
A more localized version of this is the Rio Tinto's Pilbara Mining Complex in Australia, which is controlled by a ROC located in Perth (Mine of the future™). This

particular case will be further addressed in the case studies segment of this thesis.

This situation analysis approach also takes any sudden changes in the site situation into account. A disruptive occurrence would necessarily mean more time consumed in information relay and response planning. With the new technology a disruptive situation which in the past could take weeks to resolve, can now be dealt with in mere days.

How VR/AR relates to this is that with smart sensors on the machinery, the wearables of the workers and real-time mapping of the terrain via sensor and drones. Combined with powerful processing of modern computers and visualization capabilities of modern programs, the experts have a lot more access and hands-on point of approach to a given situation as opposed to traditional means of phone calls or written descriptions via emails, also far faster and more objective.

Humans are capable of unintentionally distorting information if they are panicking or under severe stress. This could lead to fatal miscalculations. Data through sensors and visualized through VR is objective, aiding the process of coming up with and executing countermeasures.

4.3 IT/OT Convergence

What IT/OT Convergence means in practice is the linking of IT (Information technology) systems such as cloud-based working environments and operating systems that work on many different platforms (Examples: Google applications, Microsoft applications) with OT (Operational technology) systems, which often are specific to an actual machine, or at least, the vendor.

Traditionally, different departments of an average mining company would use different systems and approaches when taking care of their respective fields, and thus have very different departmental cultures.
This would lead to major clashes and confusion whenever said departments would have to work on something together, with potentially catastrophic results to the company.

Fortunately, the companies have begun to realize and tap into the massive potential that is information accessible to everyone across the departments. Issues like vendor's ownerships of OT systems will provide some roadblocks, however the overall prognosis for the convergence remains positive (Connected workers: The IoT industrial revolution2015; Digital transformation initiative mining and metals industry.2017; Creagh, 2018; Turner, 2018).

How VR/AR relates to this is that with the powerful visual aids it offers, it can make communication between and across various departments much faster and more fruitful. For example, a sales negotiator may not understand much when shown an Excel data sheet pertaining to, say, the sizes of ore deposits at a given site, but visualize that data in VR and they will grasp the topic.

4.4 Asset cybersecurity

The scale and frequency of companies getting cyberattacked by hackers, tech-savvy criminals and even governments is higher than ever. Therefore, it is imperative that companies are capable of adequate protection and self-defense on this front. Asset cybersecurity is an umbrella term, which includes the tools and programs, infrastructure, training and education (also referred to as best practices) of personnel, risk management protocol and any other related subject. (Digital

transformation initiative mining and metals industry.2017; BSI Company, ; Department of Homeland Security).

With the convergence mentioned earlier, facets of companies that were previously not connected to the internet now are. This makes them a target for anyone with malicious intent. This creates a necessity to protect such facets.

How VR/AR relates to this is that it could substantially help the cybersecurity officials process data, monitor a situation and grasp what is happening more efficiently by visualizing the data, thus enabling them to respond faster to a threat.

4.5 Advanced Analytics and Simulation Modelling

Advanced Analytics and Simulation Modelling is arguably one the most if not *the* most prominent field, where VR/AR is concerned. This field covers supporting real-time decisions and prognoses regarding the future by utilizing artificial intelligence, big data and algorithms. (Digital transformation initiative mining and metals industry.2017; Harrod, 2016; Walsha, 1999)

Yours truly postulates that VR/AR can substantially accelerate the decision-making progress by visualizing the data, helping run simulations and turn data from inexpressive sheets to dynamic visuals, and thus clarify and streamline the process. This is a helpful feature for multiple fields, such as strategy planning, safety training, and even marketing.

Humans are by default visual learners and interpreters, there being a valid reason for the existence of the saying “A picture is worth a thousand words”, and this holding even more true when said picture is moving.
Utilizing the capabilities of VR and AR, the process of hazard assessment is going to be far more dynamic, with the simulations etching themselves far deeper

into human memory and psyche than what mere data sheets could ever hope to do.
It is one thing to see estimations as a row of numbers, and completely another to a witness a highwall collapse that sweeps with it machinery and people into a grisly demise, albeit only in a simulation, yours truly would argue.

Simulations, again, help with training new personnel. It is far more cost-efficient as well as significantly anxiety reducing for a new employee to learn the controls of, for example, a large dump truck or an excavator, sitting in a simulation cock-pit. In that environment, many different scenarios can be run, and the employees can familiarize themselves with the cockpit of the machine, which the simulation one of course must be identical to.

The anxiety, yours truly argues, is further reduced by the knowledge that while training, a mistake will not result in significant losses of material, any real dam-age to a real machine, or anyone’s injury or death.
As an additional offshoot and bonus, these simulations can help bridge the gen-erational and skill-gap between employees, as the two exchange expertise and knowledge, enriching themselves and ultimately the company as a whole.

Finally, VR opens significant new elements and avenues for explorations when it comes to presentation and marketing. Presenting an interactive overflight of a mining complex where the spectator can rotate the camera and zoom, pointing out and choosing specific areas and receiving an overview of them while view-ing, is worlds apart from handing out pamphlets and running PowerPoint presen-tations.

5 THEORIES APPLIED IN THIS THESIS

In this segment, we shall go over the theoretical lenses that will be used to go over the case studies and the data that they provide. Below is a brief overview of each theory and/or model, finishing with a brief sampling of them in practice.

These theories were chosen due to the marketing-oriented nature of the thesis, as well as their general academic utility when analyzing such subjects as the one being covered here.

5.1 Technology Acceptance Model (TAM)

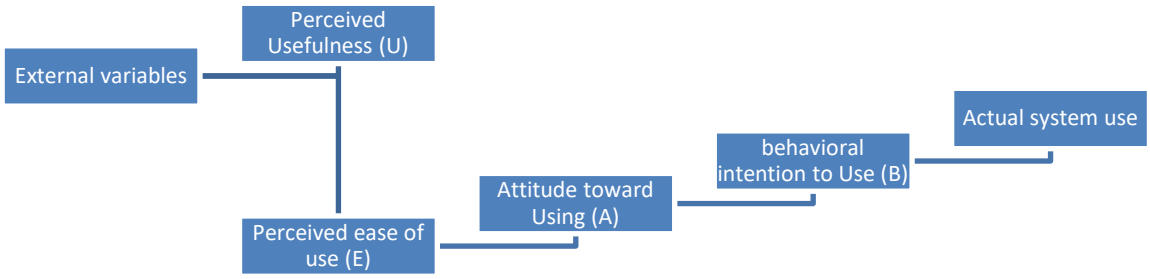

Figure 1. An illustrator of the technology Acceptance Model, based on the graphic found at an online presentation - Chapter 14 E-Commerce Strategy and Global EC. Jason Chou-Hong Chen, Ph.D. Professor of MIS Graduate School of Business, Gonzaga University Spokane

The TAM is a theory that attempts to illuminate how users come to accept new technologies and how they adapt to them. It proposes that when presented with new technology, there are a few key factors influencing the rate of acceptance and use, most notably PU aka Perceived Usefulness, and PEOU aka Perceived Ease-Of-Use. PU measures the degree to which a person would find the technology useful to him or her, and PEOU measures how easy to use said technology is perceived to be.

Being de-facto an off-shoot from the Theory of Reasoned Action by Ajzen et al, described below, TAM was first introduced in 1989 by Davis et al, and further elaborated on later.

The model proposes that based on the external variables of a given technology, these influencing the perceived usefulness and perceived ease of use, latter of which influences the former, together influence the attitude towards the given technology as well as the intent of using it, which ultimately manifest as the actual use.

An illuminating example of this is how the smartphone was adapted into our daily lives. In marketing, what was emphasized was the ease of use, and the usefulness of the device. This influenced the public perception as well as, for the most part, intentions of use, resulting in massive success.

5.2 Theory of Reasoned Action (TRA)

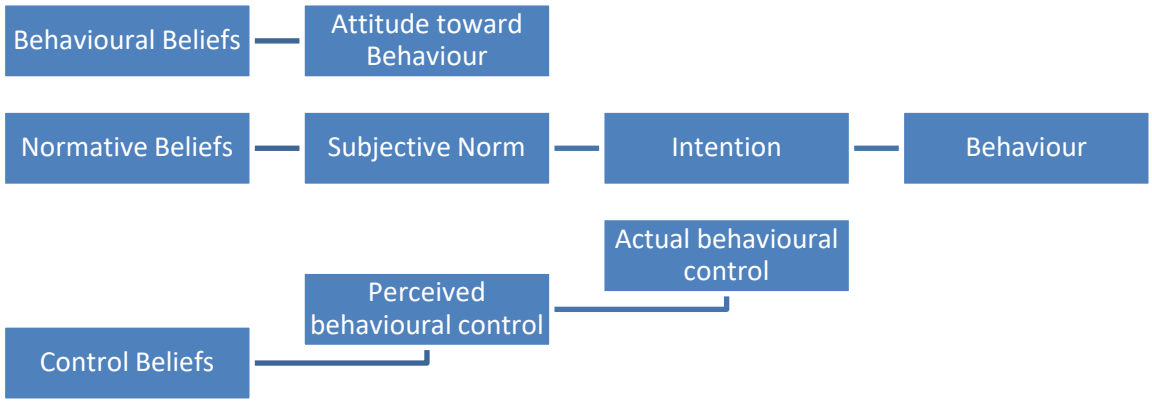

Figure 2. An illustrator of the Theory of reasoned Action, based on the graphic found in a SlideShare presentation “Persuasion Communication” by Stephan Dahl

The theory of reasoned action or TRA is the original theory from which the Technology Acceptance Model was derived. Martin Fishbein and Icek Ajzen developed TRA in 1967. The TRA aims to explain how individual’s beliefs and expectations influence their decisions and actions.

What TRA postulates is that an observed behavior is influenced by several factors: behavioral beliefs of an individual and the attitude toward said beliefs held by the same individual, the subjective norm and the normative beliefs associated with it, and finally, the control beliefs and the perceived behavioral control.

These six interconnect, and together influence intention of a person, which in turn results in the observable behavior.

5.3 PESTEL analysis

The PESTEL analysis aims to define and categorize the six main categories of influence factors in a given business venture. This theory is included to cover instances like market penetration, as when entering a new market and during the process of self-establishment, all of the influencers covered in PESTEL should be noted in order to avoid setbacks that a thorough analysis could have prevented.

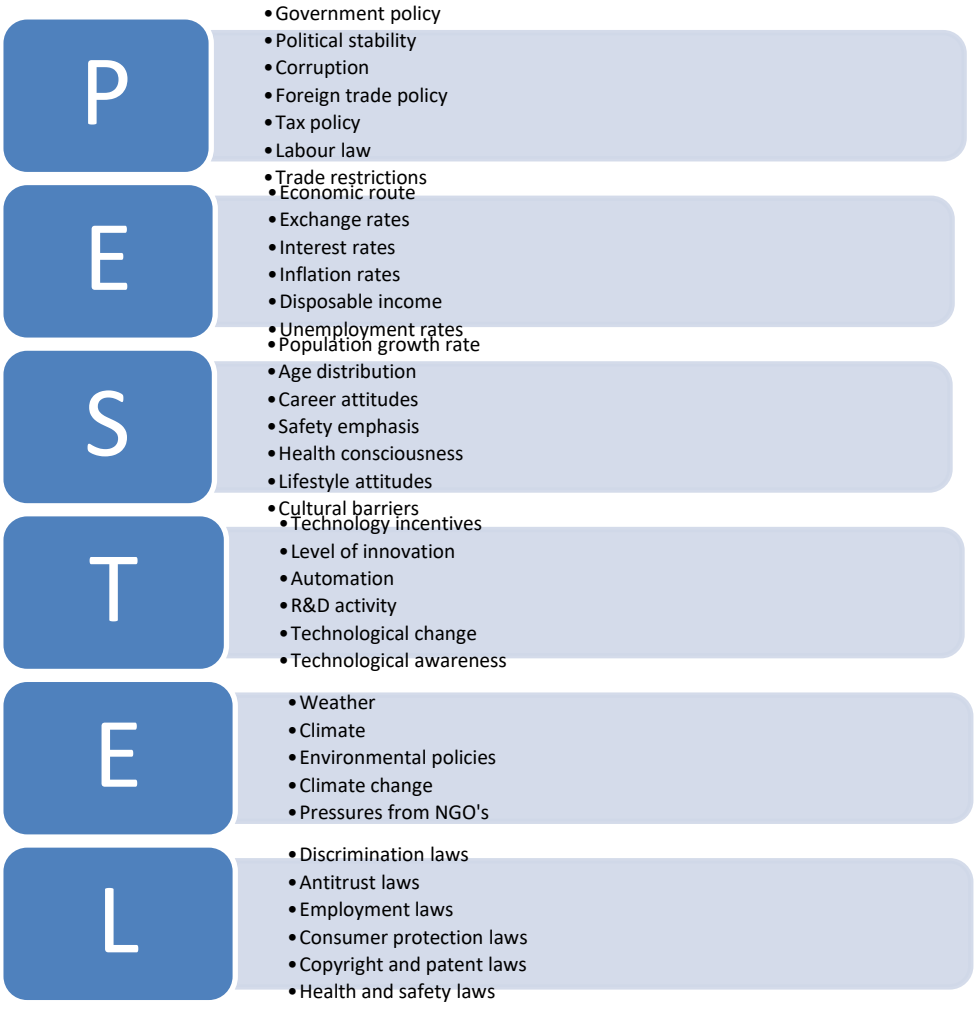

Figure 3. An illustrator of the PESTEL Analysis based on the graphic found at business-to-you.com's page, article "Scanning the environment: PESTEL analysis"

Political category covers things like government, foreign trade and tax policies, political stability and corruption, and trade restrictions.
Regarding the mining sector, influences that would fall into this category are ones such as the resource nationalism, which was mentioned earlier.
Regarding VR/AR, this pertains to things such as government policy and trade restrictions on soft-and hardware related to VR/AR.

Economic category refers to things such as economic growth, exchange, interest and inflation rates, disposable income and unemployment rates.
Regarding the mining sector, this refers to things like stock market position, plans regarding the operations of a mine, and hiring policies.
Regarding VR/AR, this would cover aspects such as hard-and software production costs, the structure of the supply chain from a financial perspective, etc.

Social category means factors like population growth rate, age distribution, career attitudes, safety emphasis, health consciousness, lifestyle attitudes and cultural barriers.
In the mining sector, this would mean aspects like work environment and safety, company culture, global networking and transparency.
In relation to VR/AR, this would mean all of the above, as well as marketing choices and research.

Technological category covers technology incentives, technological innovation, research and development activity, technological change and technological awareness.
In the mining sector, that means areas such as discovery of a better method to drill, or the debut of a new type of industry machinery.
In VR/AR, this means the influences hard-and software developments have on honing the product.

Environmental category refers to factors such as weather, climate, environmental policies, climate change and pressure from NGOs.
In the mining sector, this means things like governments restricting or limiting certain actions, like mining at a specific location, environmental monitoring, etc.
In VR/AR, this means things like responsible sourcing of raw material needed for the headsets etc.

Legal category encompasses influences like discrimination laws, antitrust laws, employment laws, consumer protection laws, copyright protection laws and health and security laws.
In both the mining sector and VR/AR, this means all legal aspects in any part of producing and selling the commodity. As might be expected, this category heavily overlaps with the others.

The PESTEL analysis is beneficial to run to more clearly map out a situation of any given company at any point. Unfortunately, it by itself is too broad, thus more focused models come into play, one of which will be introduced below.

5.4 Consumer Decision Making Process

This process refers to the steps that ultimately lead to a customer making the conscious decision to purchase a commodity.

Figure 5. An illustrator of the Consumer Decision Making Pricess, based on the graph found at a WordPress blog “Consumer Psychology Web”, article “Consumer Decision Making Process”

Need recognition is the first spot, wherein the need for a commodity is identified. Example would be “Annie needs a car.”

Search for information is the second step, wherein the customer searches for information in relation to their need, in order to identify all the factors that influence their ultimate choice and narrow down all existing commodities that would answer their need, in short, to make an informed choice. Example would be “Annie does an online search and finds deals on cars A, B and C.”

Evaluation of alternatives is the third step a direct continuation from the second step, and it refers to analyzing all gathered data on the various choices. Example would be “Annie learns that car A has features X, Y and Z, car B has features 1, 2 and 3, and car C has features Red, Blue and Yellow.”

Purchase decision is the fourth and semi-final step, even if many would have considered it the final one, in the past especially. This step is directly influenced by the results of the third step, contrasted against the specific needs of the buyer. Example would be “Annie chooses car B because it suits her needs the most.”

Post-purchase evaluation is the real final step, and it means all further related actions the customer makes after the purchase, whether said actions are fueled by satisfaction or dissatisfaction.
This step is very important, reason being that if the expectations of a customer are not met and bad, damaging information on a commodity provider starts circulating, this can be fatal, as it will render any marketing strategies in place void, the trust held in the provider by society will evaporate and sales will plummet.

On the flipside, an experience exceeding the original expectations will serve as a powerful marketing tool and an advantage in social visibility, aiding the provider’s standing considerably. Example here would be “Annie really loves car B and encourages her family members and friends to buy cars from the company that makes car B.”

5.5 Marketing Mix 7Ps

Edmund Jerome McCarthy developed the marketing mix in 1960. There exist two versions, the first one consistingof four Ps (Product, Price, Place, Promotion). The second form, utilized in this thesis, is the expanded seven Ps version. Each P will be covered here briefly.

What the 7Ps Model contributes to the marketing field is that it introduces several points of observations through which the existing situation can be analyzed, thus revealing various factors that influence the ultimate manifestation of a marketing

strategy that a marketer would not necessarily notice on their own, human perception being very individualized and not free of influences.

Thus, the 7Ps help broaden the vision of a strategy planner, ultimately birthing a stronger, more thorough strategy.

Figure 5. An illustrator of the Marketing Mix 7Ps, based on the graph found at a web article at professionalacademy.com, “Marketing Theories – Marketing Mix – from 4Ps to 7ps”

Product refers to whatever commodity is offered. Analyzing a commodity through this P means in practice that one gets deeply familiarized with it, becoming aware of the commodity’s strengths and weaknesses, applications and other defining characteristics. Knowing the commodity well helps in building a solid marketing plan.

Process means the whole act of delivering the commodity to the customer. That means every step from obtaining the raw materials to polish and packaging, if need be, are under observation.

Place refers to the availability options of the commodity for the customer to purchase. Calibrating this segment properly is vital to capturing value.

Price refers to the monetary compensation that is asked for the commodity. What the price will be is greatly influenced by commodity-specific factors such as producing posts, supply and demand, as well as the nature of the supply chain.

Promotion refers to marketing in the most direct manner. In practice, this P analyzes the commodity and several other influencers such as the target market and goes on to define best ways to promote the commodity to said audience.

Physical Evidence means the physical objects that essentially “prove” that a business transaction happened.

People segments refers to the human resources the company has. Having the right people in right places is essential to success in value capturing.

6 CASES AND OBSERVATIONS

Below represented are four case studies from the field of mining where VR/AR elements are either being incorporated or could successfully be, improving the desired results. First the cases will be overviewed, after which they will be inspected through the theoretical lenses introduced earlier. Finally, a brief conclusion of the situation will be presented.

6.1 Case Study: Rio Tinto – The Mine of the Future

6.1.1 Overview

In 2008, Rio Tinto, which is an Australian-British global mining company, launched a program called “Mine of the Future”. The program aims to develop new and improved ways to extract minerals located deep underground with minimal effects on the environment, as well as reducing workplace hazards as much as possible.

To this end, they are employing tactics like Autonomous Haulage Systems (AHS), which is an ambitious endeavor to fully automate the hauling trucks and the railway system, still in testing stage, and a fully functional Operations Centre, commissioned in 2010, which is a Remote Operations Centre (ROC). They also employ an Autonomous Drilling System (ADS), which was successfully trialed at their West Angelas mine in 2008 and is now in the process of being adopted into use across of all the Pilbara Complex.

The Mine of the Future Program is being ran at Pilbara mining complex in Australia. It is a network of 16 iron ore mines, four independent port terminals, and a 1,700-kilometer rail network with related infrastructure, which all together help

the Pilbara complex to rapidly respond to changes in demand. All this is supported and monitored from the Operations Center located in Perth. (Mine of the future™.; Connected workers: The IoT industrial revolution2015; Digital transformation initiative mining and metals industry.2017; Tracking the trends 2018 the top 10 issues shaping mining in the year ahead.2018)

6.1.2 Analyze through theories

TAM & TRA: The technology acceptance model as well as the theory of reasoned action model display themselves here in how Rio Tinto's perception of automating processes and monitoring the mines from afar is beneficial for the company's bottom line as well as their employees is affecting the rate and readiness of their adoption of new technology.

PESTEL: The categories most prominent here are Economic, Social and Technological.
Economic covers the decision to automate; making the trucks and the trains operate remotely cuts costs significantly.
The social category is related to it, in the sense that should there be a malfunction and an accident; far less human lives are in danger. It influences the Economic factor in the sense that it focuses on minimizing risks to employees and by that, reducing costs to the company as accidents are reduced.
Technological category comes into play with all the new, still developing technology and solutions they have adapted to achieve this outcome.

Consumer decision making process: In this case the information on the product provider is limited, thus only a vague overview is possible. The process, by logic, must have gone similarly to the following: Rio Tinto, looking for a more efficient way to keep track of their drills, haul trucks, warehouses and railways, com-

missioned a remote operations center. This need was met by a company/developer as of yet unknown. However, it is known that Rio Tinto's initial tests have been successful, thus their post-purchase evaluation seems to be positive, enough so to make public statements about the success.

7Ps: Less prominent here as this project is mostly focused on manufacturing and does not provide many moments easily translatable to the marketing medium. The "Process" P can be seen here in action however, as the whole complex has been designed to rapidly respond to fluctuating commodity demands.

6.1.3 Conclusion

Rio Tinto is generally known to adapt new technologies at a rapid pace for the mining sector. VR/AR is not really present here, however future potential in, for example, monitoring mine data via VR visualization could be fruitful.

6.2 Case Study: Freeport-McMoRan – Using Drones to Monitor and Evaluate the Rock Face in Real Time

6.2.1 Overview

Rather than risking the lives and health of their employees, Freeport-McMoRan has opted to using drones to survey rock-face in real-time. This enables them to simultaneously cut significantly the costs that would have arisen from all the needed safety precautions were they using humans to survey, as well as seeing the rock face from angles the human surveyors would not even be able to see.

Thanks to the modified military-grade drones equipped with cameras that stream video in real time, the surveying process is safer and more accurate than ever.

The drones have actually been adapted to document much more than just the rock face. These would be highwalls, large mill buildings, traffic flows and power lines. (Robots and drones: Automation on the rise.; Freeport McMoRan: Using cutting-edge tech to monitor the mine environment.2018)

For their efforts, the company was recently decorated with an award from the National Institute for Occupational Safety and Health (NIOSH) (NIOSH Recognizes Three Mining Companies with Innovation Awards, Stephanie Stevens, 2017).

6.2.2 Analyze through theories

TAM & TRA: Again, a very good demonstration of both theories, as the company's perception of the usefulness as well as the ease of use of the new technology. The sizeable savings in resources, equipment and safety training of personnel add to the appeal. Unpacking the case, it looks like following:

External variables would in this case be things like the terrain, the technology at hand, the funding, and the expertise needed to operate the drones, establish the footage streaming, also the pre-existing skills in the workforce, time-frames for training, etc.

Perceived usefulness shows in the fact that the company has deemed it far easier, safer and more cost-efficient to pilot the drones and scan the chosen environment than it is to train, safely equip and deploy employees.
Moreover, should a work-related accident happen, it is far easier and cheaper to acquire a new drone, as opposed to dealing with the consequences of a work-related injury or death of a human being.

Perceived ease of use would in this case be the attitude held about learning to pilot a drone with an already adjusted camera, as opposed to teaching a person

rock climbing and the use of scanning or filming equipment. The latter consumes far more time, and the propensity to human error and forgetfulness leading to accidents is higher.

Attitude towards using the drones looks to be positive as the practice continues. This is based on the actual use, which has yielded positive results, and thus is continued.

Behavioral intention to use is one informed by the external factors, as well as the company agenda, based on the perceived usefulness and perceived ease of use. In this case that means boosting the area monitoring while minimizing costs by keeping employees safe.

Actual system use is almost identical to the perception, intention of use, as this is a business environment, since due to the drones belonging to the company, and their use is heavily regulated.

Behavioral beliefs >> Perceived behavioral control >> Intention >> Behavior – schema of the TRA closely follows the pattern showed by the TAM breakdown, with the mild variation possibly being that any changes in perceived behavior, which would affect the attitude held, versus the actual behavior of all actors in a situation.
This could possibly somewhat influence the outcome, as perceptions are molded to correspond with the reality. Important to note here is that the perceived behavioral control can be influenced by any and all of the existing external factors, which includes the human element aka the employees.

Example: During a piloting training session, it is discovered that the person being trained has trouble with their depth-vision and thus evaluates distances incorrectly, resulting in either more training or change of pilot trainee.

PESTEL: The categories most prominent here are again Economic, Social and Technological.

Economic covers the decision to switch the optics from human to machine and thus cutting costs, using the same logic that was already established in the TAM and TRA analysis.

Social category is related to it in the same way the earlier case was, in the sense that should there be a malfunction and an accident; far less human lives are in danger. Another element of the category is represented in the effort of training the personnel to use the drones, thus expanding their personal skill repertoires and possibly cultural understanding as well.

Technological category comes into play with all the new technology and solutions they have adapted to and modified in order to achieve this outcome.

Consumer decision-making process: Again, the data on the selling party in this case is severely limited; however, the buyer's process can be deduced to be something like the following:

Needing a safer and more precise manner of environment scanning and hazard assessment (need recognition), Freeport-McMoRan likely put out several inquiries (search for information), choosing the one being analyzed here as the most fitting option (evaluation of alternatives and purchase decision).

Evidently, the final step, post-purchase evaluation, has been a positive one just like in the first case study, prompting official statements and even web articles on their current scan method.

7Ps: Unlike with the first case study, this scenario is actually far more “media-attractive” and has many points easily utilizable outside the primary purpose and in any marketing and PR endeavor that the company might undertake.
Thanks to the drones and other visual elements connected to the endeavor, the documentation of the processes can be presented in engaging videos on social media platforms. This factor thus actually expands their usefulness.
The Ps covered in this case are:

Product refers to whatever commodity is offered, which in this case are the drones, the cameras and the video streaming software.

Price refers to the monetary compensation that is asked for the commodity. Given that we are observing the case from the buyer’s point of view, this would indicate that the price for the product has been reasonable and preferable as opposed to combined potential costs related to have the rock face scanned via people climbing down it in person.

Physical Evidence means the physical objects that essentially “prove” that a business transaction happened. This, in the given setting, would be the drones, cameras and the software.

6.2.3 Conclusion

By utilizing modern technology, Freeport McMoRan has found a way to more effectively scan the environment, as well as keep their employees safe, and thus reduce cost while simultaneously raising their productivity.

Unlike with the first case, there are many opportunities for utilizing VR/AR here, both in the real, actual mining work itself, as well as the marketing side of things. For example, a real-time VR flyover tour of a mine presented at a fair would be a

visually stimulating and dynamic add to the PR/marketing endeavours of the company.

6.3 Case Study: Mira Geoscience – Providing 4D Geotechnical Hazard Assessment

6.3.1 Overview

Mira Geosciences is a Canada-based company founded in year 1999 that, according to their webpage, provides consulting services and specific software for companies working in the mining sector.
Their software solutions are geared towards exploration and evaluation of areas, as well as hazard assessment.

These softwares use 3D and 4D modelling combined with advanced data processing to map and evaluate the areas, creating a complete picture of the location by combining and visualizing different data sets such as rock type and quality, seismicity, structure, geometry and so forth.

Based on the data obtained, the programs create fully visualized assessments, complete with weighted risk analyses.
These analyses have been employed globally to address hazards such as rock bursts, slope stability and roof fall threats. (Katarv Shannon, 2017; Mira Geoscience, ; WJ McGaughey Mira Geoscience Ltd. et al., 2017)

6.3.2 Analyze through theories

TAM & TRA: In this case, the perceived usefulness of the product plays the biggest part, supported by the perceived ease of use.
Naturally, any given company is interested in raising the bottom line by preserving the safety of its employees, and the clear design of these softwares helps them to achieve that goal. The ease of use is demonstrated via the 3D and 4D visualization, making the data far more interpretable than traditional data sheets. Unpacked, this is how it looks:

External variables in this case are, rather similarly when compared to the last case, the nature of the terrain which will be analyzed, the hard-and software specifications that will need to be optimized to run the solution, the finances of the buyer company and finally the expertise required to use the solution.

Perceived usefulness is here, as was stated earlier, possibly the biggest individual influencer. The perceived usefulness in this case refers to the way the company that buys the software perceives the environment scanning and hazard assessment to influence their bottom line. This would be achieved via savings based on good strategic choices made after seeing the results of the scan and data analysis.

Perceived ease of use directly supports the perceived usefulness, in the way that Mira Geosciences either directly teaches via workshops or provides documented instructions to use the software solution. This, in the end, is more cost-effective than safety training and various other workshops mandatory for employees in order to train them to go out in the field and perform the hazard assessment.

Attitude towards using is that of positive expectation, as increased safety, increased geospatial knowledge of a given area and through the aforementioned two, informed decisions that lead to monetary savings are the main drivers.

Behavioral intention, largely the same as in the last case, is informed by the external factors as well as the company agenda. It is based on the perceived usefulness and perceived ease of use, again, similarly to the last case. In this case that means boosting the area awareness in regards to hazards as well as acquiring detailed geospatial knowledge that monitoring while minimizing costs by keeping employees safe via informed decisions and actions.

Actual system use is near identical to the behavioral intention, due to the influence of the attitude towards the use, as well as the strictly controlled environment. The only deviating instances are probably, just like in the analysis of the last case study, related to the individual diversities of the external factors, for example, the competency levels of the employees.

Behavioral beliefs >> Perceived behavioral control >> Intention >> Behavior – schema of the TRA is rather straightforward – The company believes that the hazard assessment is useful, this leads to, owing to the fact that a company/business setting is very purpose-oriented and thus streamlines actions of all related actors.
This leads to the perception of the behavioral control to significantly to mold the intentions of the participating actors, and thus effects the end behavior in a straight manner.

PESTEL: Prominent categories here are Technological and Social, as this is a rather straightforward case of utilizing technology to increase the safety of the workers.

Technological bracket of course refers to the software solution, and by extension the hardware used to run it.

Social bracket means the increased security as well as performance of the employees, owing to the increase of accuracy regarding both hazard assessment as well as the geospatial scans regarding the potential an area holds.

Consumer decision making process: Since Mira Geosciences is a developer/provider company as opposed to a customer, given the context of the research, the consumer decision making process theory cannot, unfortunately, be applied in this case study.
Yours truly does concede that given an interest, the process could be “reverse-engineered” and deconstructed to possibly serve as a product optimization strategy, however truthfully there are already such theories in place and thus it is not needed.

7Ps: The Ps featured here are People, Process and Physical evidence.

People here refers to the employees and the effect increased safety will have on them, as well as the confidence boost in decision-making processes thanks to all the data that the solution provides them.

Process is about the actual task of mapping of the areas, acquiring data in regards to all possible hazardous elements in the area that is under analysis. Another example of process is the informed decision-making based on the potentially influential pieces of information the geospatial analysis will have on the business strategies of a given company going forward.

Physical evidence refers to the 3D and 4D maps and graphs, which will be the “physical” manifestation of the software and its use, as well as, by extension, the required hardware.
On some level, the skillsets that the employees will have to develop to successfully operate the software solution to achieve desired outcomes could be classified as a physical evidence as well.
Moreover, one could even argue that an absence can be used as physical evidence in this case, the absence referring to the decrease in workplace injuries,

material and equipment loss as well as a decrease in decisions that ultimately prove less profitable than estimated, all thanks to the preventive qualities of the hazard assessment.

6.3.3 Conclusion

Out of the case studies covered so far, this one utilizes computer-generated imagery the most and as such has greatest VR/AR adaptability. VR can be used during the hazard assessment as well as the visualization of big data, giving prognostics a much more dynamic form to be presented.

From a marketing perspective, the dominant visual aspect is very easy to utilize in marketing, through stills and videos. The safety and effective prevention manner as well as data processing are also major points to promote.

6.4 Case Study: Rio Tinto, Anglo American, Newcrest Mining – Using Smart Headwear to Monitor Fatigue Levels

6.4.1 Overview

As demonstrated by the title, in this case it is not just one company but three that have been using a technology called LifeBand by SmartCap Technologies, an Australian company.

The product is a combination of a headband fitted with sensors that performs periodic electroencephalogram (EEG) scans on the wearer and a Bluetooth-connected mobile app called LifeApp, which stores and shows the performance of

the user. The bands can be fitted into a hard hat, a baseball cap, a beanie, or even worn as is.

The scans keep track of the user's brain activity and fatigue levels using an algorithm and will alert the user before a phenomenon called a "microsleep" occurs, thus keeping them safe (SmartCap technologies: Our product.; Thinking caps test fatique.2015; Ker, 2015).

6.4.2 Analyze through theories

TAM & TRA: Another strong example where the perceived usefulness (keeping the employee safe) and perceived ease of use (no calibrating the band, just connect it to a hat and connect to the app) influence the decision to buy and use.

PESTEL: Prominent categories: Social and Technology, social referring to the wish of the companies to keep their employees safe and thus save in money and other relevant resources otherwise spent on responding to accidents, equipment repairs etc., and technological refers to the hard-and software utilized in this case.

Consumer decision making process: Based on the data found, the process in this case went as follows: The three mining companies, concerned about the general wellbeing as well as the performance of their employees, set out to find a device and/or method to keep track of them. SmartCap Technologies had a product that matched their needs, and thus they purchased it. And once again, the post-purchase evaluation has been positive, thus the companies keep using the product.

7Ps: The Ps featured here are People, Process and Physical evidence.

People here refers to the employees and the effect increased safety via the brainwave monitoring will have on them. Process refers to the use, and the ease of it, of the product, both the band and the app. The physical evidence in this case is the band, and the app, in the sense that it is ran via a smartphone which is a physical object.

6.4.3 Conclusion

While there is no VR/AR component linked to this particular case or product, the possibility to incorporate them in order to boost the effectiveness of the smart wearables is clear. Using AR, for example, one could transfer the data display from the phone app to a hard hat’s visor etc.

Additionally, if the data recorded goes to a company database, VR can be utilized to compile 3D graphs and big data models to store and display the information in a user-friendly manner.

7 A LOOK INTO THE FUTURE

This segment will put forth an overview of main strengths, weaknesses, opportunities and threats to VR/AR when incorporating it to the mining sector, deduced by yours truly after looking at the case studies through the theoretical lenses, as well as the articles and theses that have been used as sources for this research.

7.1 Strengths of incorporation of VR/AR into mining

Increased safety and accuracy when scanning environments: As was described in the second and third case studies, the VR can be used in a joint operation with drones, and thus make for example slope scans much safer, since the employee that is doing the scanning is safely situated in an office, watching a VR stream from the drone's camera. Even in a worst-case-scenario, acquiring a new drone as opposed to treating injuries and possibly paying pension on the basis of invalidity due to a work accident is far more economic and humane.

Easier and safer to train employees: A very similar argument as was postulated above, when an employee is safely in a VR environment in an office as opposed to in the cockpit of a heavy industrial machine, the price of a mistake is far less. Instead of injuries and equipment damage, even casualties, the greatest inconvenience is restarting the simulation.

Data is processed faster and is more interpretable to different people due to visual format: A notable quality of data stored in pixels is that one can store and process it faster than in regular formats. This is a significant help when handling amounts of information as big as a mining company must.

This paired with the more visually pleasing way of viewing and handling data via VR makes this medium very attractive when it comes to rapidly going over information and making sure it is memorized by the personnel. This method of handling is also far more intuitive and user-friendly, reducing workplace anxiety as well as helping to increase the know-how of individuals and through them, of the company as a whole.

7.2 Weaknesses the incorporation currently has

Still developing: The VR/AR technology is still in the process of developing and establishing itself. While this is a good thing in the sense that VR/AR will develop alongside other technologies, it also means that a lot of the applications of it are still in the experimental stage.
This is unfortunately a fact that makes mining companies already seeing an unsure and turbulent future, very cautious investors. Fortunately, all the successful experiments can be used to persuade them to give VR/AR a chance.

Often relies on internet and “plugged in” type of electricity: This can become a problem when trying to establish VR stations in locations with either less than satisfactory internet availability, or which are prone to harsh weather conditions. It might be possible to alleviate this by using LAN networks inside the mine area or assisting the local municipalities in strengthening the networks. This, incidentally, could also be turned into a marketing positive, presented as participating in enhancing local living standards.
Another problem is that due to being reliant on electricity, the hardware is practically anchored in one place. This might be completely alleviated soon however, as wireless VR sets are under rapid development.

Requires a certain level of both technology and know-how from companies to adapt: As with all new technologies, there will be a required amount of training and familiarization period for the employees.

This too, however, can be turned into a positive through using it as a springboard to unify and encourage the intermingling of different generations of employees as well as sharing of know-how, strengthening company culture and morale.

7.3 Opportunities presented by the incorporation

Lots of potential still untapped: As was covered earlier, the VR/AR field is still largely in developmental stage, and this is at a time when the development of technology in general is faster than it has ever been in human history.
This leads to the conclusion that for every task that VR is either applied for or in development for application, the general growth of technology will illuminate at least one more.

Very adaptable: An offshoot of the point illustrated above but important and distinct enough to warrant a separate mention, it is worth noting that as the VR develops in the fields of software and hardware, people both in private and commercial sectors will adapt to it. This will lead to the discovery of even more purposes for it.

Increases the individual potential of employees: As was covered earlier, should a company adapt VR/AR technologies in its regular modus operandi, training will be necessary. Earlier it was mentioned as a weakness however it is also an opportunity for personal development of the employees. This will in turn make the company as a whole more competent.

7.4 Threats to the process

Political turmoil: In the age of in essence economic warfare in the form of aggressive trade sanctions, blockades and resource nationalism, it is beneficial for both the company and the VR/AR application provider, and indeed even their supply

chain members, to always be aware of any and all political upheavals, even if at first glance what goes on in a parliament would not seem important to the mining sector.

Cyber-attacks: It is prudent to be aware at all times that in essence, whatever is linked to any kind of a network can be hacked, taken advantage of and even damaged. The variants of cyber-attacks span from industrial spying to pure malicious anarchism. This can be undertaken both by rivals as well as general undesired elements of a society and should therefore always be sufficiently guarded against.

Competition: This threat is, incidentally, the countermeasures to which yours truly personally felt. When searching for information, companies and providers alike are often rather reluctant to list the more detailed information regarding their undertakings on their pages.

For example, it was discovered that Freeport-McMoRan is using modified military drones in their monitoring, however the manufacturer/provider of said drones remains unknown, as well as the full extent of the drones- abilities.

This is of course understandable in lieu of protecting both intellectual properties as well as work and business strategies. The downside is that it makes general research rather difficult due to the vagueness.

8 CONCLUSION

In conclusion, based on the case studies it can be stated that the increasing VR/AR in the mining sector is definitely a trend that will keep on expanding through the next few decades at the very least, growing side by side with general digitalization and automatization, of course depending on the rate that the technology generally develops with.

Furthermore, it is clear that the adoption rate of VR/AR technology as well as general digitalization is a distinctly individual process, varying for every company.

The main trend noticed when analyzing the case studies were the clear emphasis on employee and workplace safety via automatization and preventive measures such as Mira Geoscience's 4D hazard assessment software and the smart headwear used by Rio Tinto, Newcrest Mining and Anglo American.

The underlying reason here is to try to cut costs by reducing workplace accidents that result in damage to both employees and worksite equipment, and thus balance out the loss that the drop of product demand coupled with increasing scarcity has caused.

That is why, for example, Freeport McMoRan is so keen to use drones instead of people climbing around the rock faces – a drone is easier and cheaper to either fix or replace than a human being.

Concluding this research, one can state that while this was indeed a mere scratch on the surface of the given topic, it can confidently be postulated that the field is one of many potentials and there is value to capture, therefore the pursuit of developing and marketing a VR/AR product is rational and justified.

As the field expands owing to the ongoing development of VR/AR technologies as well as others, more opportunities to implement VR/AR are sure to arise, opening up further possibilities for KAMK/CEMIS to adapt their product and capture more value.

The two most prominent constraints of this thesis research have been the very limited time frame as well as the lack of primary data, the thesis being mainly background research using a literature review method, and rather broadly at that.

Initially the area that was supposed to be covered was larger; however, the time constraints forced a few reductions in quantity as well as the depths and expanse of the analysis.
This is regrettable, as yours truly believes that this topic is important and deserves a deeper looking into, however the reality is that to do a truly thorough research, several years would be needed.

Thus, the thesis is indeed a general abridgement, which shall be freely admitted, however it shall be said that despite the shrinking of the area covered, owing to the diversity of the case studies picked, the key points that yours truly wanted to illuminate have been brought fourth in a satisfactory manner.

Opportunities for research are abundant.
Narrow as this thesis research is, it has illuminated a notable amount of cases in the mining field where VR/AR either already is applied but could be expanded upon or could be applied to enhance the performance and/or ease of use of a given task or a process.

Such applications and modification/enhancement opportunities are where CEMIS, by the estimation of yours truly, has a solid business opportunity and thus further development of their product is not only justified but encouraged.

An aspect severely neglected in the R&D, in the opinion of yours truly, is the effect that the unique company cultures have on the purchasing decisions. This will help in tailoring marketing strategies.

In hindsight, it was rather reckless to undertake such a massive topic under the time constraints. There are so many nuances affecting the “end result” that all of them simply cannot be addressed during the span of this thesis, forcing yours truly to depict only a general overview, which is indeed regrettable.

However, even in this admittedly rather shallow look, when analyzing the case studies, the potential of VR/AR is clearly manifest. In that regard, yours truly is rather satisfied with the results.

Applying the theoretical lenses further clarified the patterns traceable from the applications of VR/AR and the decision processes of the companies, and further illuminated possibilities related to marketing in the future.

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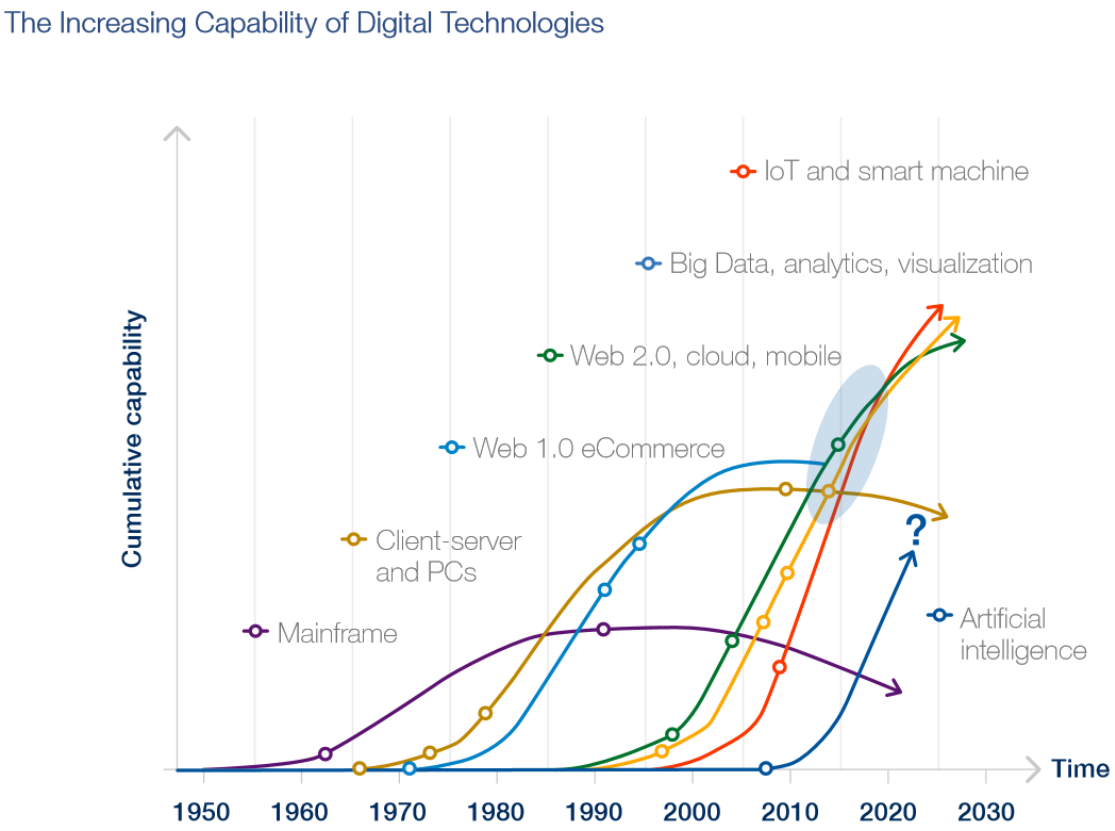
APPENDICES



Appendix 1. The increasing capabilities of digital technologies around the world, sourced from the World Economic Forum “Digital Transformation” whitepaper, also World Economic Forum/Accenture analysis